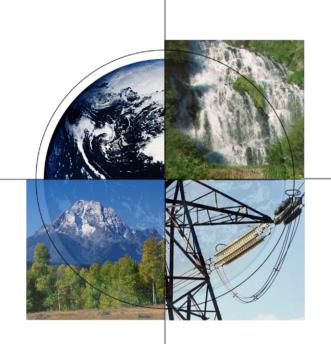
Energy, Role of Hydrogen, and NETL



West Virginia Energy Roadmap for Hydrogen Stonewall Resort Roanoke, WV

November 19-20, 2003
Rita A. Bajura, Director

National Energy Technology Laboratory





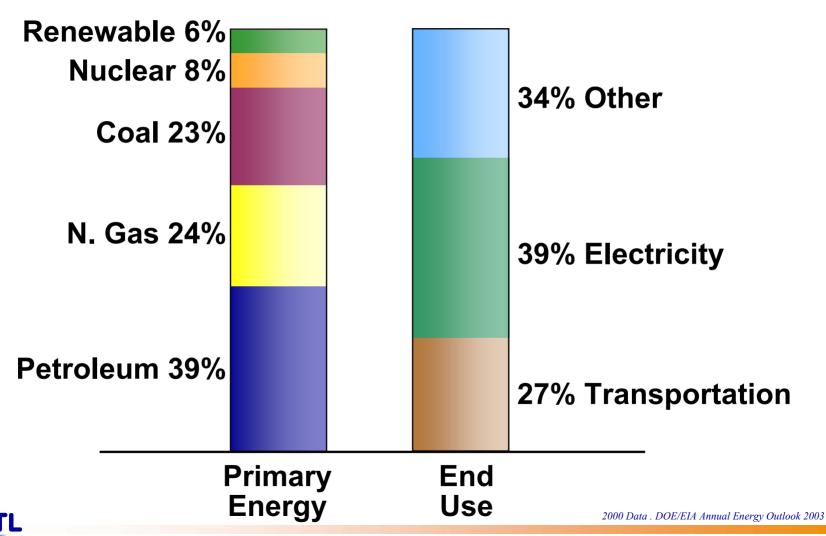
Outline

- Definition of hydrogen energy future
- Drivers
- Technology status
- WV situation analysis
- Closing comments

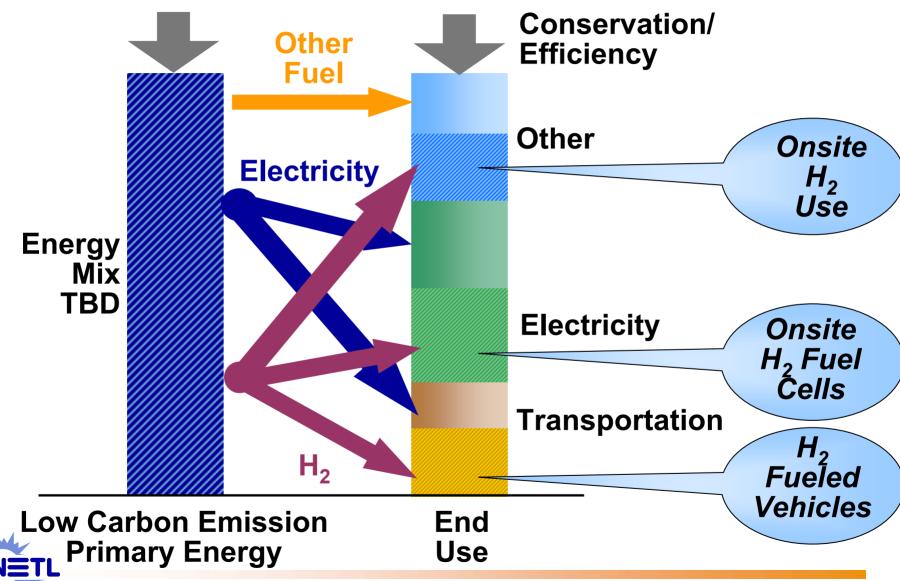




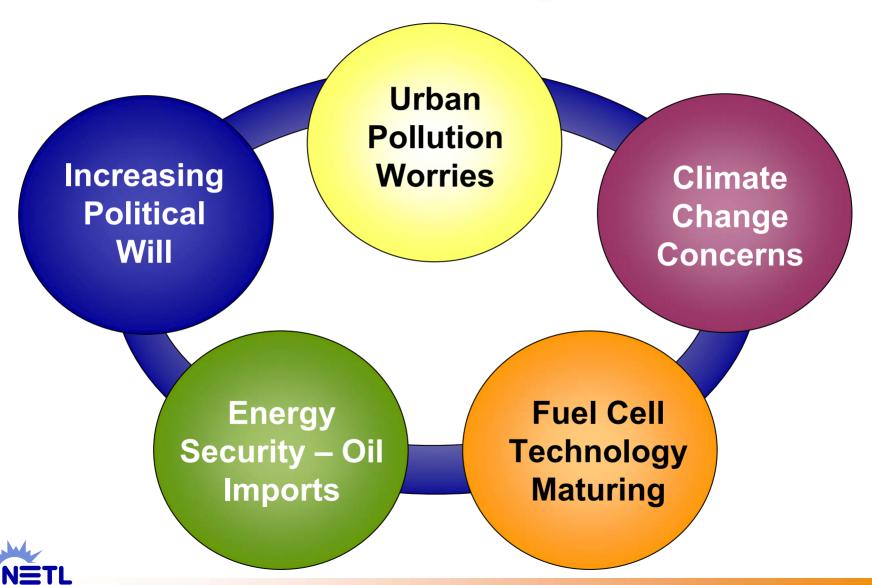
U.S. Energy Today



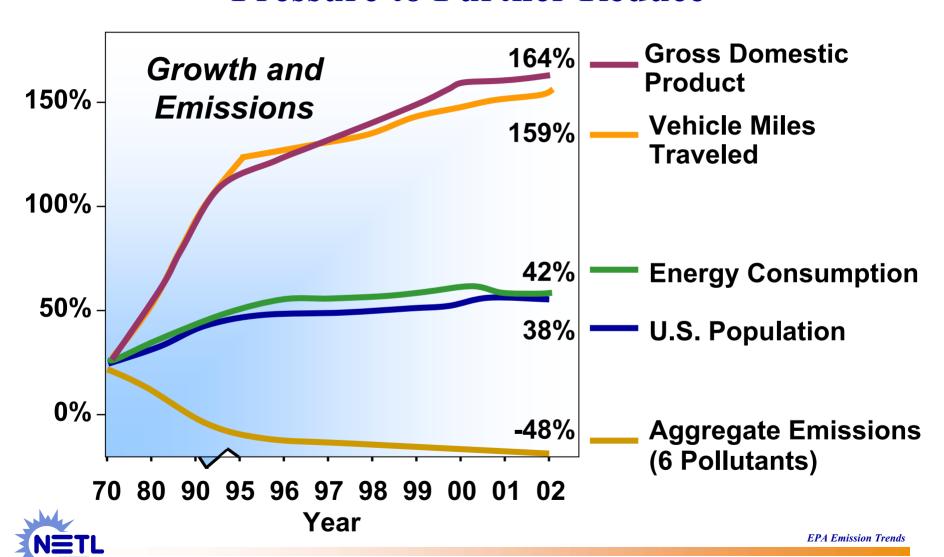
Hydrogen Energy Future: A Notional View 2050



Confluence of Drivers for H₂ Energy Future



While Air Emissions Down Sharply, Pressure to Further Reduce



CO₂ From Energy Is Major Contributor to Anthropogenic Greenhouse Gas Emissions

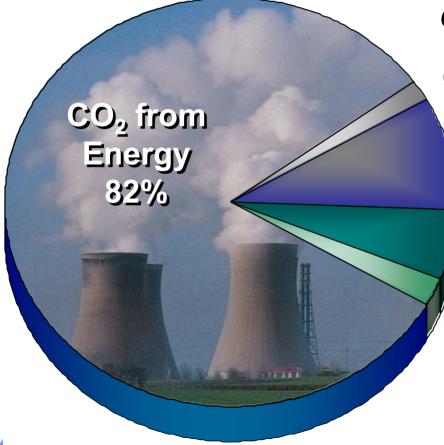
U.S. GHG Emissions Weighted by Global Warming Potential

Other CO₂ 1.7%

Methane 9.0%

Nitrous Oxide 5.6%

Other Gases 2.1%



Global Climate Change: Fact or Fiction? It Probably Doesn't Matter — The Issue Is Here to Stay

- Science unlikely to provide unequivocal causality answer
- Governments and markets likely to act on their perception of the science





Patchwork of State & Local GHG Programs

Seattle, WA: Goal of zero net GHG emissions from electric; purchased reductions from OR Climate Trust

WI: GHG registry being developed

NH: 4P legislation requiring 3 power plants to reduce CO₂ emissions to 1990 levels passed House; purchase credits from 11 NE states; GHG registry being developed

OR: New power plants - 17% CO₂ below most efficient natural gas plant; purchase credits from OR Climate Trust or approved projects

Portland, OR: 20% below 1988 CO₂ emissions by 2010

CA: GHG registry being developed

OK: Law allows OK to certify carbon sequestration from changes in farming practices

MA: Law requiring 10% cut in CO₂ emissions from 6 power plants; may purchase CO₂ offsets; GHG registry being developed

NY: GHG Task Force established; recommendations for federal 4P reductions

TX: GHG registry being developed

NJ: GHG reduction target of 3.5% below 1990 levels by 2005; voluntary generation of GHG credits/banking in NJ credit registry

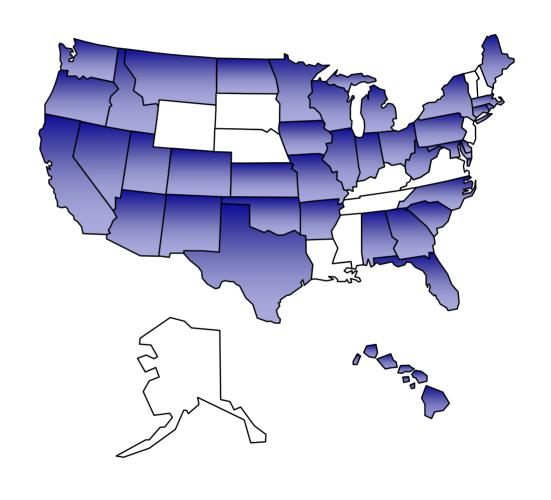
Neil Cohn, Natsource Emissions Desk, April 30th, 2002



States With Incentives for Renewables

38 states have one or more incentives:

- State income tax credit
- Renewable portfolio standard / goal
- State / utility / local buydown program
- State grant program





Fuel Cell Technology Maturing

Phosphoric Acid

- IFC
- 220 200-kW units
- > Six "9's" reliability

Molten Carbonate

- Fuel Cell Energy
- 50 MW/year manufacturing plant
- 10 million kWh generated

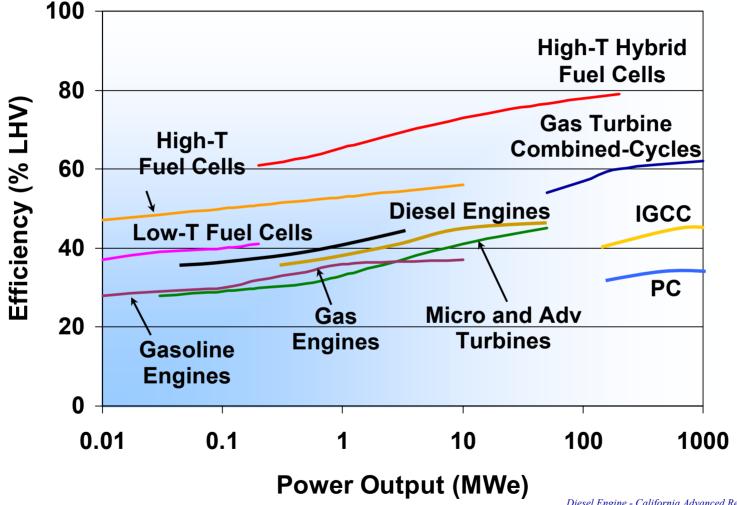






Nothing Matches Fuel Cell Efficiency

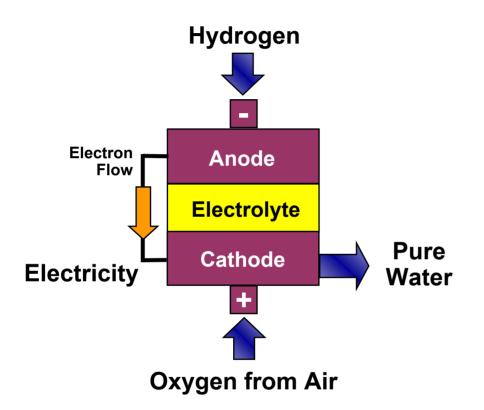
Transportation and Stationary Power





Gas Engine - GRI
Diesel Engine - California Advanced Reciprocating Internal
Combustion Engines Collaborative, Workshop Proceedings, July 2001

Fuel Cells Are an Enabling Technology for Hydrogen Future



Basically a battery with an external supply of fuel and oxidant



Cells stacked together for desired power

Issue: Cost

- Fuel cells cost \$1,600 \$4,500 per kilowatt



3-10 kW Solid State Fuel Cells for Multiple Applications



2005 Beta Prototype

- \$800 / kW
 - Premium power
 - Auxiliary power in long-haul trucks
 - Military



2010 Product

- \$400 / kW
 - Residential
 - Industrial CHP



2015

- Vision 21 power plants
- Hybrid systems







Six SECA Industry Teams







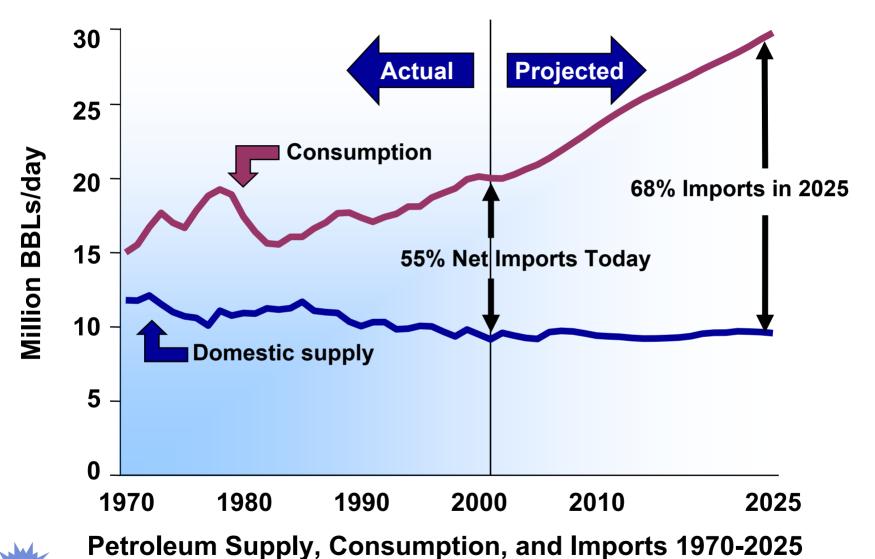






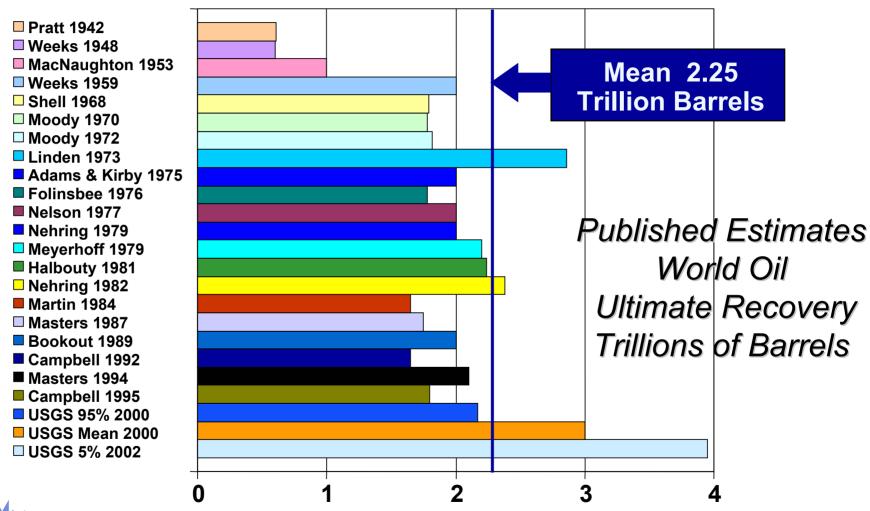


Energy Security: U.S. Oil Imports Rising



DOE/EIA Annual Energy Outlook 2003

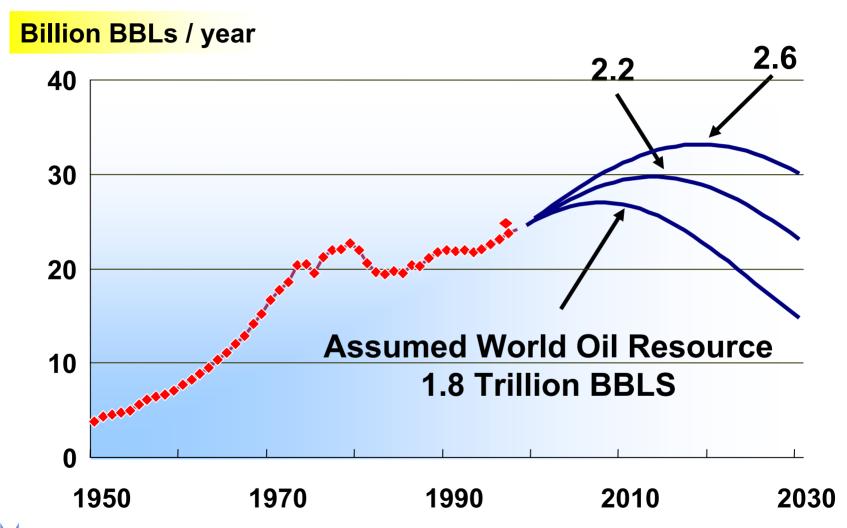
World Light Oil Supply Is Finite





USGS and Colin Campbell

Estimated Date of Peak Light Oil Production





Hydrogen Can Be Produced From Many Domestic Energy Sources



Natural Gas



Coal



Biomass



Solar / Wind



Nuclear Power

Future Hydrogen

- Fusion
- Thermochemical
- Photochemical



Biomass photo: NREL, Calvert Cliffs Nuclear Plant

Increasing Political Will

President Bush Launches Hydrogen and Related Initiatives

- Hydrogen
- FreedomCAR
- FutureGen
- Carbon Sequestration



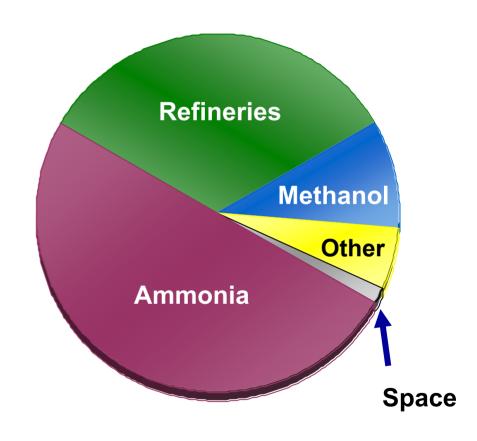






Beginnings of Hydrogen Infrastructure Exists

- World annual production equivalent to 1.5% of primary energy
- Most produced by major industrial gas suppliers:
 - Air Liquide
 - Air Products
 - BOC
 - Linde
 - Praxair
- Used principally as industrial commodity





Hydrogen Refueling Stations

CTA Chicago, IL

CaFCP



Ford Dearborn, MI



Sacramento, CA





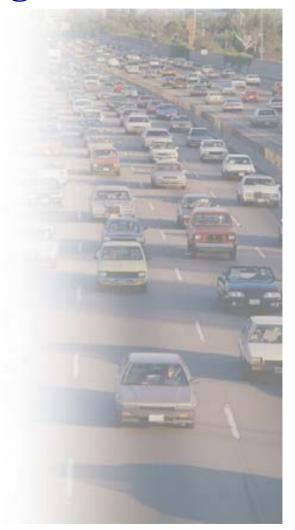


Erie, PA



Hydrogen - Inherently Good But Economically Challenged

- Not naturally occurring
 - Process derived
- Low energy density
- Safety challenged
- Expensive to:
 - -Produce
 - -Store
 - Deliver
 - Transfer





U.S. DOE Developing Hydrogen R&D Plans





DOE's Hydrogen Program Sets Goals for Infrastructure Development



Hydrogen Storage on Metal Hydrides

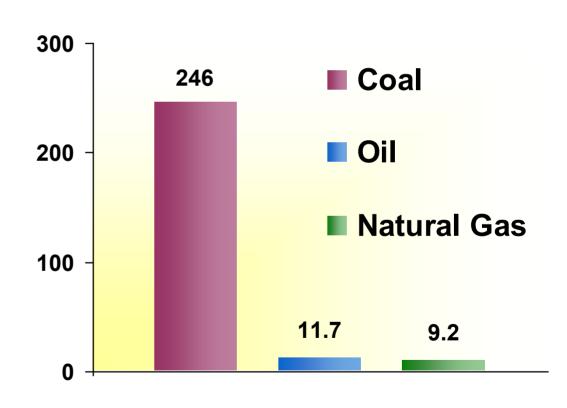




Technology Can Enable Coal to Be Preferred Source for Future H₂ Production

U.S. Fossil Fuel Reserves / Production Ratio Years Supply at Current Production

- Abundant reserves
- Low and stable prices
- Technology improvements
 - Could enable nearzero emissions of air pollutants/GHGs





EIA- U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves: 2001 Annual Report, November 2002; Coal: BP Statistical Review, June 2002, World Energy Council

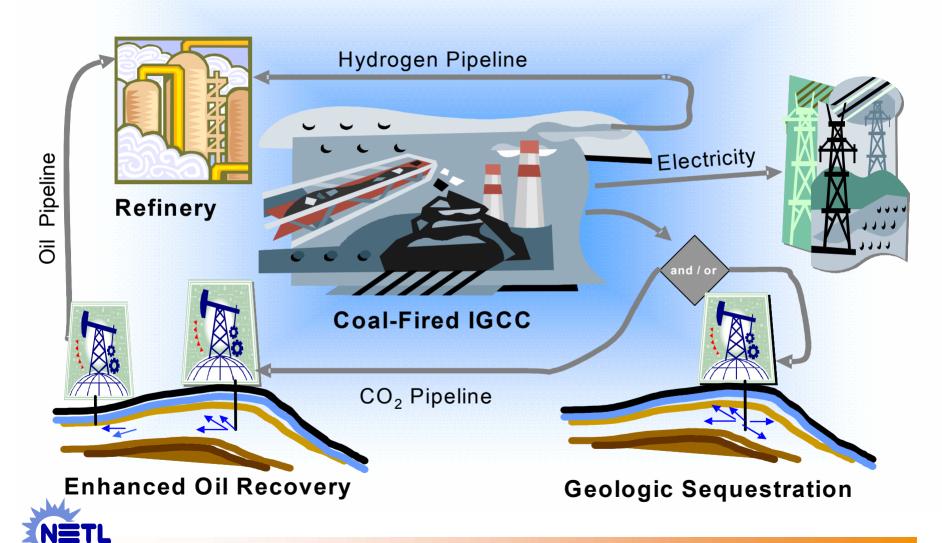
FutureGen

One billion dollar, 10-year demonstration project to create world's first coal-based, zero-emission electricity and hydrogen plant *President Bush, February 27, 2003*





FutureGen Concept



Industry Group Announced Formation of FutureGen Consortium

- American Electric Power
- CINergy
- PacifiCorp
- Southern Company
- TXU (Texas Utilities)

- CONSOL
- Kennecott Energy
- North American Coal
- Peabody Energy
- RAG American Coal Holding

Charter members represent ~1/3 coalfired utilities and ~1/2 U.S. coal industry



FutureGen Uses Coal Gasification Technology *IGCC in Early Commercialization*

Wabash River

- -1996 Powerplant of Year Award*
- -Achieved 95% availability



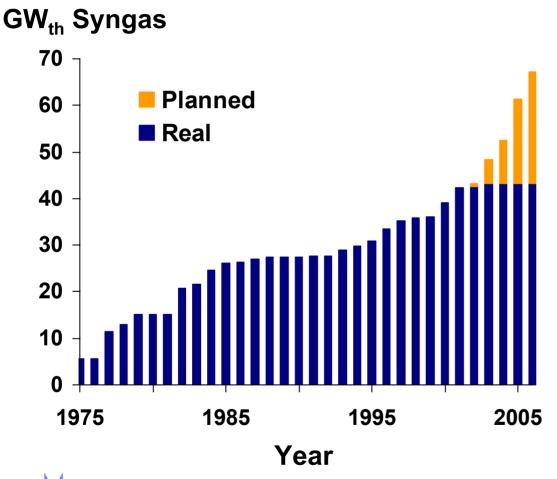
Tampa Electric

- 1997 Powerplant of Year Award*
- First dispatch power generator





Significant Worldwide Gasification Capacity Cumulative Capacity

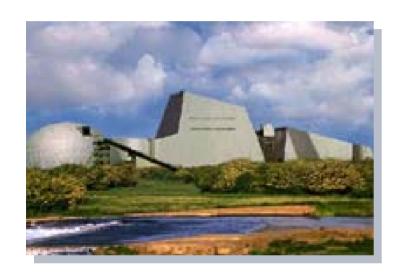


130 Operating Gasification Plants

- 400 gasifiers
- 43,300 MW_{th} of synthesis gas
- 24,000 MWe IGCC equivalent



Why Integrated Gasification Combined Cycle?



- Fuel and product flexibility
- Environmentally superior
- High efficiency
- Sequestration ready

Producing concentrated stream of CO₂ at high pressure

- Improves sequestration economics
- Reduces efficiency penalty



Approaches to Sequester Carbon

Capture and Storage



Unmineable Coal Seams



Deep Ocean Injection







Depleted Oil /
Gas Wells,
Saline Reservoirs

Enhance Natural Processes







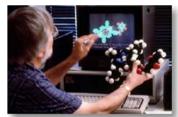
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Forestation



Iron or Nitrogen Fertilization of Ocean



Enhanced Photosynthesis



Why Sequestration Is Important

One of Three Carbon Management Options

- Switch to low- and no-carbon fuels
- Increase energy efficiency
- Sequester carbon

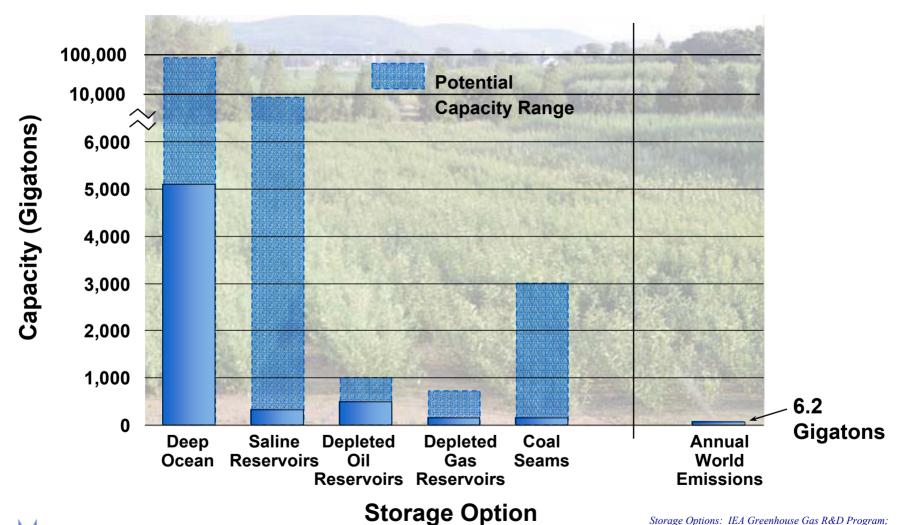
Sequestration Advantages

- Compatible with existing energy infrastructures
- May prove to be lowest cost option





Large Potential Worldwide Storage Capacity





Storage Options: IEA Greenhouse Gas R&D Program; Advanced Resources International estimates for coal seams World Emissions: International Energy Outlook 2000, Table A10

Sequestration Is Feasible One Million TPY CO₂ Sequestration Projects

Weyburn CO₂ Project

- Pan Canadian Resources
- Enhanced oil recovery coupled with sequestration

Sleipner North Sea Project

- Statoil
- Production of natural gas with high CO₂ content
- CO₂ sequestered in saline reservoir under sea







DOE Sequestration Program Is Dynamic

- Diverse research portfolio
 - -70 projects
- Strong industry support
 - -40% cost share
- \$140M value of R&D portfolio



National Energy Technology Laboratory

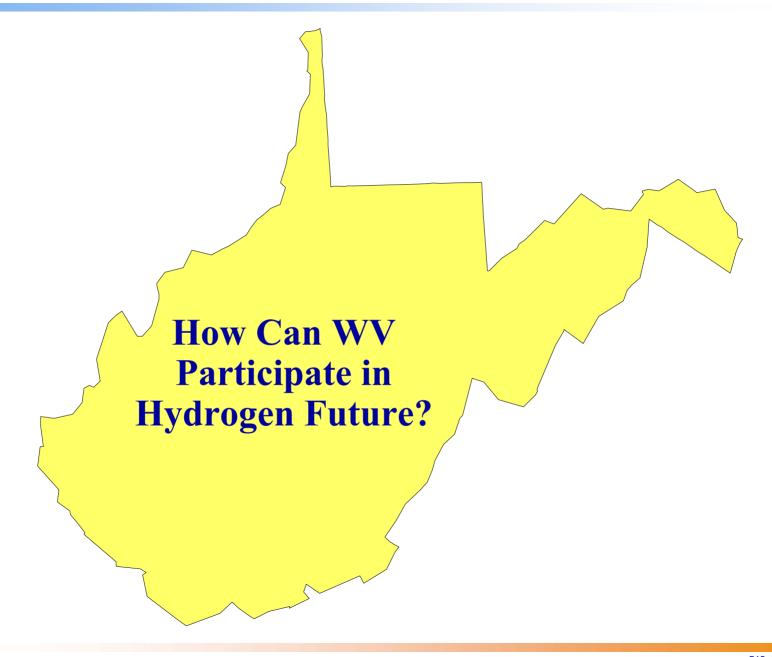






- One of DOE's 17 national labs
- Sites in West Virginia, Pennsylvania, Oklahoma, Alaska
- Implements DOE's R&D programs in coal, oil, natural gas
- 1,100 Federal and contractor employees
- \$750 million per year budget







Many States Have Hydrogen Activities

- Hawaii State H₂ Plan
- California Fuel Cell Partnership
- North Dakota Coal Gasification/Sequestration
- Florida Solar H₂ Initiative
- Michigan FreedomCar/ Next Energy
- Ohio Fuel Cell Initiative
- Montana Montana
 Energy Futures Coalition





Canadian Hydrogen Experience Stakes are Large!

• 2001-2002

- -32 companies
- -\$97 million revenue
- -\$179 million R&D
- -1,772 jobs
- Projected 2002-2003 growth
 - -\$165 million
 - -\$358 million R&D
 - -2,639 jobs





Hydrogen Industries

- Engineering
- H₂ production equipment
- Testing equipment
- Fuel cells
- Power generators
- H₂ storage
- H₂ transportation
- Distributed energy equipment
- Pressure devises
- Pressure regulators
- Evaluation and certification services

- Electrical components
- Purification services
- Engines
- Safety products
- NO_x reduction
- Fuel reformation
- Gas sensors
- Carbon sequestration
- Coal gasification
- Safety training
- Many more to come

Coal in West Virginia

- 16,200 payroll jobs
- 99% of electricity produced using coal
 - -Average cost \$0.05/kWh
- 54 billion tons coal reserves
 - Produced 163 million tons in 2002
- Contributes 13% to State GDP
- Coal and electricity industry pay 60% of WV's business tax





The Hydrogen Economy in WV: 2002, Alzate and Will, Bureau of Business and Economic Research, July 2003

U.S. CO₂ Emissions From Fossil Fuel Combustion

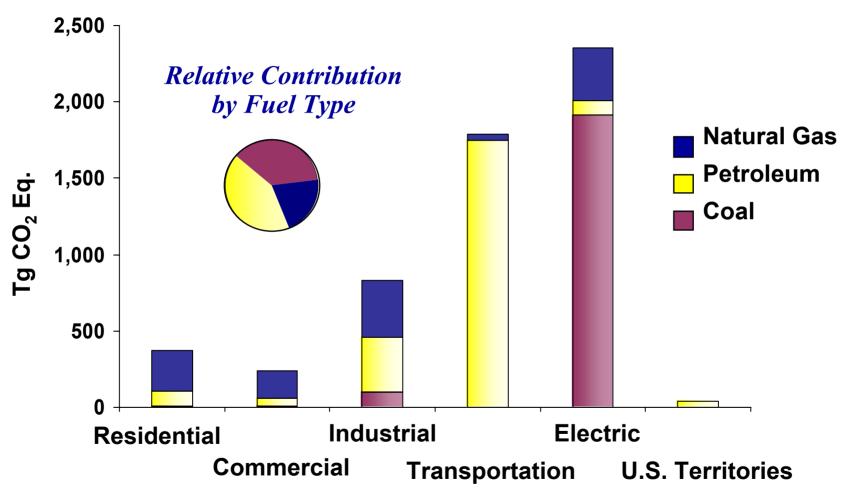
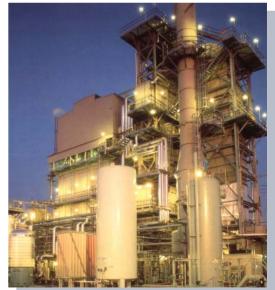




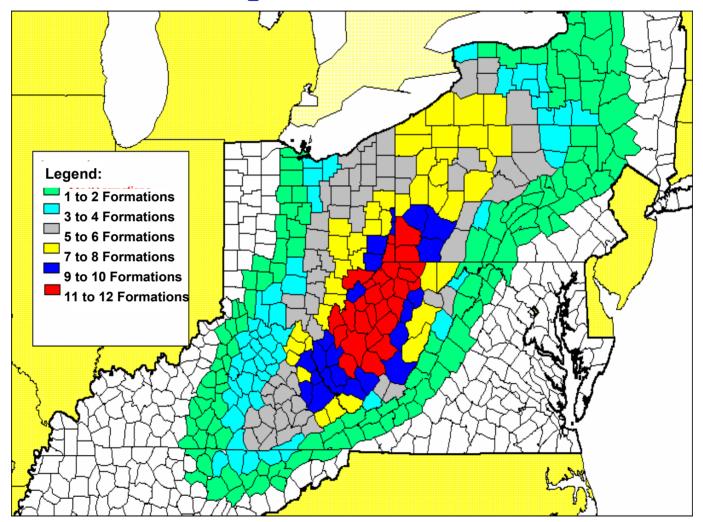
Table 2-3, EPA 430-R-02-003, April 2002 Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000

West Virginia Situation Analysis

- Coal critical to WV economy and potential target for carbon emission limits
- Chemical industry has H₂ production expertise
- Research institutions have H₂ production expertise
- Potential H₂ pipeline right-ofways along pipelines/electric transmission lines
- Near east coast population centers
- Potential sites for geological sequestration



WV Has Many Potential Geologic Sequestration Sites





In Closing . . . Energy Industry Being Transformed as It Moves Toward a Hydrogen Future



Electricity Sector



Transportation Sector



Coal Gasification/Carbon Sequestration Path Is Promising

 U.S. has an abundance of coal easily enough to get to 2100

 We have technology to gasify coal and sequester CO₂

 Coal-based H₂ and electricity production with near-zero carbon emissions appears less expensive than most other approaches



For West Virginia . . .

Gasification plus carbon sequestration provides opportunity for coal:



To continue to be used for electric production



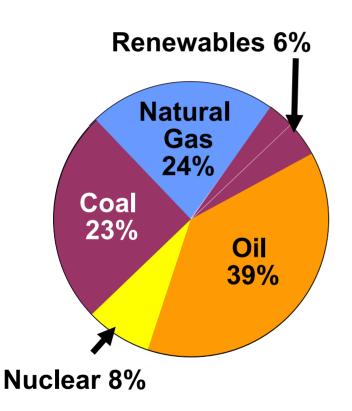
To produce H₂ and capture portions of transportation fuel market

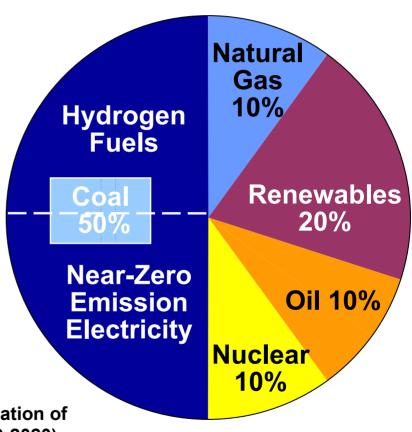


Where U.S. Could Be in 2050

Today







Total projection an extrapolation of EIA "Reference Case" (1999-2020)



Based on Ray Smith, LLNL, Southwest Renewable Energy Conference, Flagstaff, AZ, August 7, 2003

Should There Be a WV Hydrogen Initiative?

Should It Focus on Coal-Based Hydrogen Production?

